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ADJUSTING MONTANA'S AGRICULTURE

Agricultural Research Provides Information On Which Sound Adjustments Are Based

Forty-Fourth Annual Report
of the
Montana Agricultural Experiment Station

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MONTANA STATE COLLEGE
AGRICULTURAL EXPERIMENT STATION
BOZEMAN, MONTANA
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FOREWORD

The Montana Agricultural Experiment Station through the years is endeavoring to serve the residents of Montana who have an interest in agriculture. The many sided approach to the service is shown by the following present-day objectives of the Station program of agricultural research.

1. **Conservation of land and water resources:** Studies of crop rotations and fertilizers and their effects on soil productivity have been major projects since the Station was organized. So also have studies on conservation and use of irrigation water, tillage methods to conserve moisture on the non-irrigated crop and range lands, soil surveys, land classification, soil erosion control, and land utilization.

2. **Increased efficiency of agricultural production:** The cost of production per crop or livestock unit must be materially reduced if the producer of agricultural products in Montana is to successfully meet present-day competition. This is possible only if research points the way through experiments in crop and soil management practices, farm management, animal feeding, and studies to control insects and diseases injurious to plant and animal life.

3. **Improving the quality of and the market for agricultural products:** The Station seeks to improve the market for farm and ranch products of this State. This involves breeding programs to produce crops and types of livestock better adapted to Montana, and investigations of production practices for both plants and animals to determine their effects upon keeping and shipping qualities and by improving quality thus to increase consumer demand, and studies to develop new uses for products of agriculture.

4. **Improvement in the home:** The Station is serving the family in the home through research into food and nutrition problems related to health, into efficiency of home equipment to reduce labor, and studies of wearing qualities of various items of clothing.

5. **Planning a more satisfactory rural life:** The Station hopes to contribute to the pleasure and satisfaction of living in rural districts through investigations of the standards of living, rural organizations, population trends, property valuation and taxation in relation to public institutions, social services, and land utilization.

6. **Scientific research as a foundation for agricultural progress:** Much of the work of the Agricultural Experiment Station of necessity deals with studies the results of which have almost no immediate practical application. Sound progress in agriculture is possible only through original and fundamental research which provides new knowledge of the sciences which are involved in the practices employed by the producers on their farms.

The significance of agricultural research to farmers and ranchers in Montana has been clearly expressed by the late Dean H. W. Mumford of the University of Illinois: "Good farming does not happen. There could be no good farming without superior varieties of crops and types of livestock, without reliable cultural methods and sound marketing practices. The principal source of all these aids to good farming is agricultural research. The history of superior livestock, higher quality crops, better dairy products, reduced cost of production, and improved marketing practices, is largely the history of agricultural research. Farming will be good farming only as it changes its methods to meet changing conditions. Farming methods cannot be changed intelligently until research points the way."

ADJUSTING MONTANA'S AGRICULTURE

by

Clyde McKee, Director

INTRODUCTION

CONDITIONS WHICH NECESSITATE ADJUSTMENT

The historian who records the various steps in the development of Montana's agriculture will present a chain of circumstances which provide ample justification for present-day efforts at adjustment which have as their objective the establishment of the agriculture of this State on a more permanent and profitable basis. Perhaps the first agricultural efforts in many parts of Montana were by men who took up farming in certain small valleys to produce some of the staple agricultural products which sold readily in the mining camps. Next came the stockmen with large herds of cattle and bands of sheep, to harvest the forage which had supported many thousands of buffalo, elk, deer and other game animals, on the millions of acres of grazing lands in the main range of the Rocky Mountains and on the plains area to the east.

The success of the valley farmers was due largely to the irrigation water obtained from small streams. This provided the encouragement for the next important step in Montana's agriculture, viz, the development of irrigation in the larger valleys, where in a comparatively short time, some of the larger irrigation projects in operation today were built.

The soldiers, on returning from the Civil War, urged more liberal homestead laws, which were enacted in 1872. These were designed to transfer public land into private ownership as quickly as possible and eventually resulted in the very rapid settlement of the Middle West. Fifty years or more ago, some farmer on the small irrigated farm, seeking to enlarge his crops, ploughed an area of dry sod land above his irrigation ditch, planted it with grain and obtained a very fine crop. He repeated this on an in-

creased area in succeeding years and again with success and spread the news that crops were possible on this dry land. Thus was born the term *Dry Farming,* which was intended to convey a new idea—a new method of agricultural practice applicable to farming the dry lands of the West. Man's enterprise spread the vision of this possibility for the vast area of the level range pasture (the base of the western livestock industry) and by the thousands, settlers moved in to possess the land, from the valley farms of the west, out onto the dry benches; and in the east, from the prairie farms of the Middle West, into the great plains extending to the Rocky Mountains. Most unfortunately they moved in before there was any definite information about the climate and soil conditions of these various areas, or whether or not they had possibilities of successful farming. These movements were also facilitated by the homestead laws that settled the Middle West, and also the amendments enlarging the homsteads to 320 and 640 acres, which were requested by the settlers taking up the Great Plains area. This Homestead Era in Montana started about the beginning of this century during a series of years when the rainfall was somewhat above average, with the result that settlers filed on and cropped millions of acres of land suitable only for grazing. The use of submarginal land for farming was further encouraged by the combined influences of high wheat prices during the World War, the favorable moisture conditions, the fertility of the virgin soil, and the introduction of large scale labor-saving machinery. These and a series of drought years combined with the agricultural and national depressions were the more important factors in the chain of circumstances which have affected the development of Montana's agriculture.

This story of the experiences in land settlement in Montana is little if any different from that of other states, particularly those in the Great Plains area. Moreover, from its beginning, neither the state nor the nation has had any clearly defined land-use policy—the chief purpose seeming to be to attract settlers and transfer the public lands to private ownership as rapidly as possible. Systems of agriculture were used which disregarded almost entirely the natural climatic and soil conditions; but perhaps with the forces urging settlement at the time, the agricultural development of Montana could not have

been accomplished otherwise. Be that as it may, the citizens of Montana now find it necessary to make important adjustments in the use of these agricultural lands if agriculture is to be established on a permanent and profitable basis.

ADAPTING AGRICULTURE TO A SPECIAL ENVIRONMENT

If Montana's agriculture is to be permanent and profitable on a long-time basis, it must be adapted to the environment prevailing in the larger part of the Great Plains area. This area is characterized by (1) limited annual precipitation with rather extreme seasonal variations, (2) fairly high evaporation, (3) low humidity and (4) rather high average wind velocity especially during certain seasons of the year. Soils also are variable in most parts of the Great Plains.

As moisture is the limiting factor in production either of native forage or agricultural crops on much of the land area of the State, it is essential that land use policies be developed which will permit the establishment of farm and ranch units capable of being adjusted to these seasonal variations in the natural moisture supply. Seasons of subnormal precipitation with subsequent short crops will occur in the future as in the past; thus, permanent agriculture cannot be established unless these facts are recognized in the development of future policies to govern the use of these lands.

AGRICULTURAL RESEARCH ESSENTIAL

To get the basic factual information upon which to develop a sound and satisfactory land use policy, thorough, careful, and detailed research is necessary. As all phases of the agricultural problem must be studied, much time and many helpers will also be required.

Fortunately there is in each state an agricultural experiment station, authorized by State and Federal legislation to conduct exhaustive and impartial research into these many and varied agricultural problems. The Hatch Act of 1887 outlined the functions of the Agricultural Experiment Stations quite plainly by stating that they were "to aid in acquiring and diffusing among the people of the United States, useful and practical information on subjects connected with agriculture, and to pro-

mote scientific investigation and experiment respecting the principles and applications of agricultural science."

Year by year, the Montana Agricultural Experiment Station has been studying some of the many and diverse problems with which farmers, ranchers, and other citizens interested in agriculture have been confronted. Working in the interests of Montana agriculture since 1893, this Station has made many notable contributions to agricultural knowledge and to the application of this knowledge to practical agriculture. Once each year the Director's Annual Report has summarized briefly the results of the various research departments, while numerous bulletins, circulars, special reports and press articles have given detailed information on various problems under investigation.

During the recent period of adjustment in the agricultural industry, many Federal, Regional, State, County and Community agencies have discovered the need for an immense amount of basic agricultural information. It is worth noting that the Montana Agricultural Experiment Station has been supplying and is preparing to supply much of this information, and through cooperative agreements with various State, Federal and other agencies, is continuing to gather and make available additional information.

ORGANIZATION FOR AGRICULTURAL RESEARCH

Montana is a large state with a wide variety of soils and with climatic conditions which are highly variable in its many regions and in different seasons. Thus, no one location for agricultural experiments can render the farmer and stockman adequate service. The State, therefore, has organized its Agricultural Experiment Station so as to serve several rather distinct regions.

The headquarters of the Montana Station is at Bozeman, in connection with Montana State College, and serves as the central agency of the State for agricultural research. The work at this central station is supplemented by five branch stations scattered rather widely over the State.

THE MONTANA AGRICULTURAL EXPERIMENT STATION

The central research agency at Bozeman consists of twelve departments, each conducting studies on problems in their special fields, as follows:

Agricultural Economics: This department studies the economic problems of agriculture including the factors which influence the production, distribution, processing, and the consumption of agricultural products.

Agricultural Engineering: This department investigates the engineering phases of agriculture.

Agronomy: Investigators in this field work on the problems of crop production, of soils and of soil management.

Animal Husbandry: The problems of breeding, feeding, management and marketing of livestock receive attention in this department.

Botany and Bacteriology: This department has the responsiblity of conducting fundamental research on physiological and pathological problems of plant production.

Chemistry: Chemical research furnishes much basic information which is essential to the correct interpretation and solution of many agricultural problems.

Entomology: This department studies the life histories of injurious insects and works out practical methods for their control.

Montana Grain Inspection Laboratory: Grain and seed questions are answered through (1) grain inspection and grading, (2) protein testing, (3) milling and baking tests, (4) seed testing, and (5) seed inspection.

Home Economics: The investigators devote their time to studies of problems of the home, including foods, nutrition, clothing, home equipment, etc.

Horticulture: The horticulturists investigate problems connected with the production of tree and bush fruits, vegetables—including potatoes, flowers, trees, shrubs and other decorative plants.

Irrigation and Drainage: This department is primarily responsible for the solution of the engineering phases of irrigation and drainage problems on the farms.

Veterinary Research Laboratory: Investigators in this laboratory devote their entire time to studies of diseases and other troubles of domestic animals and in working out methods of control.

THE FIVE BRANCH STATIONS

The five branch stations are located and their research programs are planned to serve the special types of agriculture found in their respective regions. Three of the stations, those near Corvallis, Havre and Moccasin, are State-owned while those near Huntley and Miles City are owned by the Federal Government. Cooperative relations, including financial support for the research work in progress, are maintained with the United States Department of Agriculture at all of the branch stations except at the Horticulture Branch Station.

The Horticulture Branch Station near Corvallis occupies 30 acres of land and centers its attention on studies of fruit and vegetable problems of the Bitterroot and Flathead valleys in western Montana.

The Huntley Branch Station located on U. S. Highway No. 10, east of Huntley, in Yellowstone County, uses 194 acres of irrigated land and 170 acres of dry land for field studies with grain and forage crops. In addition to these investigations,

studies have been undertaken on dairy herd improvement and irrigated pasture projects. The dry-land experiments determine what may be accomplished on the heavy lands under very limited annual rainfall. The results of investigations under irrigation are applicable to the irrigated lands in the Yellowstone and Big Horn valleys, and in other valleys with similar soil and climatic conditions.

The Judith Basin Branch Station near Moccasin uses approximately 600 acres of land in conducting experiments with crops, soils, and livestock under the high bench land conditions which prevail in the Judith Basin of central Montana.

The North Montana Branch Station near Havre occupies 2000 acres of land formerly a part of the Fort Assiniboine Military Reservation. Experiments with crops and soils are producing results which are finding practical application throughout much of the "Hi-line" territory of northern Montana. In addition, a breeding herd of approximately 150 high quality grade Hereford cows is maintained, studies with which provide information of value to the producers of range cattle.

The United States Range Livestock Experiment Station includes approximately 57,000 acres of southeastern Montana range land in western Custer County, near Miles City. While the Federal Government provides the land and a substantial budget, the Montana Agricultural Experiment Station maintains a herd of approximately 700 Hereford cattle of good grade breeding and approximately 175 horses of the draft and saddle type. The cooperative studies with the United States Department of Agriculture in which this livestock is used are providing information which will be helpful to range livestock producers generally and especially those operating in eastern and southeastern Montana.

AGRICULTURAL RESEARCH AT THE CENTRAL STATION

RESEARCH IN AGRICULTURAL ECONOMICS

For many years agricultural research was centered largely on the problems of production. As agriculture became more and more complicated and competitive, a need developed for information on more efficient methods of production; and in addition it became necessary to provide information on the numerous new economic and social problems which were arising.

By means of impartial studies of the operations of large numbers of farmers and ranchers and probems which they encounter, the agricultural economists are making available much information of practical value to both the producers and consumers of agricultural products.

The types of studies undertaken by the members of this department are illustrated in the following paragraphs:

ECONOMIC AND SOCIAL IMPORTANCE OF IRRIGATION—Montana ranks fourth among the states in acreage under irrigation with 1,594,912 acres, or 1.7 per cent of the total land area, classed as irrigated. However, irrigation is practiced to a greater or less extent on 27 per cent of all farms in the State. In 1930 the value of all lands in farms, including buildings, was $527,610,002; while the irrigated land in farms, including buildings, was valued at $190,057,936, or 36 per cent of the total. Also, irrigated land provided homes for 33 per cent of the people who lived on farms.

These figures furnish an interesting comparison, viz, that while only 1.7 per cent of the total land area of the State is classified as irrigated, yet the irrigated area provides 27 per cent of all farms, is valued at 36 per cent of the value of all farm lands in the State, and furnishes homes for 33 per cent of our farm people.

Since agriculture is a basic industry, it is necessary that agricultural production and income be as stable as possible from year to year in order that dependent and closely related industries may carry on necessary exchange of goods and serv-

ices and maintain employment and production in their fields. Impartial and unbiased appraisal of the agricultural opportunities in Montana points to the fact that irrigation wherever economically feasible, makes intensive agriculture possible and produces stability of production from year to year. Thus, irrigation development deserves important consideration in planning adjustments in the agriculture of Montana. Stability of production and income in agriculture as well as in other lines of business is necessary for stable local, county, and state governments, and for the social services which are now regarded as necessities.

Other studies reveal the fact that irrigation development is a matter of wide-spread interest, and it is one in which all of the benefits do not accrue to the farmers and ranchers who are served by the irrigation ditches. Since the benefits of irrigation are widely distributed, the costs of irrigation development rightfully may be regarded as an obligation of society in general in which all elements of society should share.

Studies have been made on most of the larger irrigation projects to determine the size of farm and type of farming which will provide a satisfactory labor income for the farmer and his family. (See Bulletin 354.)

MECHANIZATION OF FARM OPERATIONS.—During recent years, marked changes have occurred in the relative importance of the many factors in agricultural production, particularly those of wheat production on non-irrigated farms. Many farm operations have been mechanized in an effort to increase efficiency by decreasing labor costs and to better adapt production practices to the prevailing climatic and soil conditions. Mechanization of wheat production has resulted in major cash obligations for farm machinery, with fuel and oil accounting for a large proportion of the annual farm expenditures. Twine has been largely eliminated and harvesting reduced to one operation through the use of the combined harvester-thresher.

Under prevailing climatic conditions the season available for the various field operations of wheat production is very short; consequently, there must be a balance between the investment in equipment and the time necessary to perform the field operations within the limits prescribed by the climate. If too much

equipment is purchased, the investment per acre will be an excessive burden to the farmer, while if equipment is inadequate, the farmer may suffer from seriously reduced yields because of inability to accomplish important operations in the proper season.

Detailed studies of the economics of wheat production are providing reliable information on the most efficient combination of machinery and land of known productive capacity, and also dependable data on the costs of labor, fuel, oil, depreciation, interest, repairs and servicing. (See Bulletin 344.)

ECONOMICS OF RANGE LIVESTOCK PRODUCTION.—A large part of the new agricultural wealth produced annually in Montana is derived from livestock and livestock products. It is logical, therefore, that the Department of Agricultural Economics should devote considerable time to a study of the economic problems of range livestock production.

Important adjustments are imperative if the production of range livestock is to be placed on a stable basis, free from the fluctuations which have been so disastrous in the past years. As rapidly as time and available funds will permit, grazing lands in each county are being classified according to carrying capacity over a long-time period. Economic studies of hundreds of Montana stock ranches show the lease prices which the users of these grazing lands can afford to pay. Studies of the tax rates now in effect on these lands clearly indicate a valuation much in excess of their earning capacity for grazing. Data now available strongly suggest that adjustments to stabilize the livestock business will require (1) grading or classification of grazing lands according to their long-time capacity to carry livestock, (2) valuation of these grazing lands according to their capacity to produce on a long-time basis, and (3) management or control of these grazing lands by private, semi-public, or public agencies to insure restoration and maintenance of forage resources at a fair average carrying capacity. (See Bulletin 341.)

Data now available make it possible for stockmen to determine the most efficient combination of livestock and land of various grades to provide a satisfactory standard of living for the rancher and his family.

A recent publication (Bulletin 358) makes available information regarding the markets used by Montana cattlemen and the trend of marketing practices during recent years. Another publication (Mimeo. Circular 7) explains the livestock auction as a new method of selling and buying livestock in Montana.

PROBLEMS OF AGRICULTURAL FINANCE.—During recent years, considerable attention has been given to studies of the problems of financing agriculture. A study just being completed has endeavored to determine the factors of farm organization and management which are most closely correlated with successful long-term borrowing by ranchers and farmers in Montana.

"Montana Farm Bankruptcies" (Bulletin 360), published recently, explains how farm bankruptcies and their disorganizing effects upon farm enterprise and community stability may be curbed: "Bankruptcies and farm failures can be reduced in the future by (1) basing loans on the productivity value of the lands as determined by a scientific soil survey and average yields and prices; (2) assessing lands for tax purposes in line with such productivity value, thereby reducing costs and increasing debt paying possibilities of the farmer; and (3) adjusting annual loan repayments to current income and in terms of buying power rather than dollars."

Farm taxation studies have been undertaken to determine the principal factors associated with high farm delinquency and methods by which such delinquency and resulting agricultural instability may be reduced. The chief factor responsible for farm tax delinquency is the present method of assessing Montana farm and ranch lands at values in excess of their true productivity or ability to pay. Other important factors contributing to delinquency in farm taxes include (1) type of farming, (2) size of the operating unit, (3) farm price levels, (4) wheat yields, etc. (See Bulletin 286.)

Other studies are in progress to determine how adjustments may be made in certain farm and ranch areas to provide for the proper support of essential public services if a considerable reduction of the tax base occurs from adopting the method of assessing farm lands according to their productivity value.

These examples of research into problems of agricutural

finance point the way to adjustments which will greatly increase the stability of agriculture in Montana.

SOCIAL PROBLEMS OF AGRICULTURAL ADJUSTMENT.—In making adjustments in land use which will provide greater stability to the agriculture of the Great Plains, some very important social problems are encountered. Changes in land use may necessitate changes in educational facilities, school districts, county governments, and other services in which people are concerned. (See Bulletin 325.)

Emergencies such as drought may result in material reduction in the population of some areas with corresponding increases in the population of more favorable areas. Such population shifts may cause serious disturbances and create "problem areas" from the standpoint of the relation between people and resources.

Study of relief shows an unbalanced condition between the population and the resources available for use. Proper adjustment means for some, rehabilitation on the present holdings through reorganization of existing farm and ranch units. For others, proper adjustment involves resettlement and relocation of population within the State and perhaps between states. For still others, adjustment calls for lesser dependence upon a single commercialized source of income and greater reliance upon self-sufficient living. (See Bulletin 343.)

In Montana the irrigated lands present an opportunity for a population pattern which is vastly different from that which is possible on the non-irrigated farming and grazing lands. For much of Montana's land area, future plans for land use must provide for social and community organization that can be supported by an agriculture adapted to a Great Plains environment.

RESEARCH IN AGRICULTURAL ENGINEERING

The engineering phases of agriculture require careful study both on the farm and ranch and in the laboratory. With definite trends toward mechanization of the major farm enterprises, there will be an increasing demand for agricultural engineering service.

During the year, field work has consisted of tests on tractors adapted to burn as fuel the grades heavier than gasoline, investigations of the use of water wheels for water-lifting

and other purposes requiring power, studies of runoff and soil erosion control, and miscellaneous observations. Work was continued on redesigning and constructing a home-made irrigation pump adapted to low lift.

The various enterprises of which farming and stockraising are composed apply engineering principles in all phases of production, processing, and conservation, and also in the home.

RESEARCH IN AGRONOMY

Information obtained from the investigation of crop and soil problems is destined to occupy an essential place in adjustments designed to place agriculture on a more stable and profitable basis.

SOIL SURVEY—AN INVENTORY OF SOIL RESOURCES.—Sound agricultural adjustments are dependent upon proper use of land and water and other agricultural resources. Proper land use can-

TABLE 1.—COUNTIES COVERED BY RECONNAISSANCE SOIL SURVEY

Name of county	Bul. No.	Name of county	Bul. No.
Blaine	228	McCone	*
Broadwater	*	Meagher	*
Cascade	337	Musselshell	*
Chouteau	252	Petroleum	363
Custer	*	Phillips	199
Daniels	174	Pondera	291
Fergus	355	Roosevelt	179
Glacier	274	Sheridan	158
Golden Valley	*	Teton	332
Hill	246	Toole	273
Judith Basin	349	Valley	198
Lewis and Clark	*	Wheatland	*
Liberty	273		

*Soil survey reports for these counties in process of preparation—publication to be announced later.

not be determined with any degree of accuracy until the soils have been studied by technically trained men and mapped to show the extent and location of the various types. A soil survey provides an inventory of the soil resources and furnishes reliable factual information which is absolutely essential to sound agricultural development.

In making a reconnaissance soil survey in Montana,[1] a county is selected as an operating unit. The surveyor makes a scientific

[1]In conducting soil surveys in Montana, the Agronomy Department of the Montana Agricultural Experiment Station cooperates with the Bureau of Chemistry and Soils of the United States Department of Agriculture.

examination of the various soils and defines on a soil map the location and extent of each soil type found in the county. In addition, a map is prepared to differentiate the level or tillable land, from rolling and hilly land and badlands. Information is collected on the amount of each square mile of land under cultivation at the time the survey was made. Detailed notes are taken on the characteristics of the different soils, the vegetative cover of grazing lands, and crops which predominate on the land under cultivation. Later historical records of crop yields are obtained, and the best available climatic data are assembled.

By combining the information on soils, topography, vegetative cover, climate and productivity as indicated by crop yields and grazing practice over a period of years, it is possible to interpret the reconnaissance soil map in the form of land classification maps, on which the land suitable only for grazing of livestock is segregated from the farming lands. The land classification maps also show the different grades of farming land and grazing land, based on productivity. Up to the close of the 1937 season, the field work of the reconnaissance soil survey has been completed in 25 counties covering 41,919,360 acres or approximately 45 per cent of the total land area of the state. The names of these counties and the number of the Montana Station bulletins containing the soil survey reports and maps appear in table 1.

TABLE 2.—IRRIGABLE AREAS COVERED BY DETAILED SOIL SURVEYS

Project	Area surveyed	Report published as*
Sun River Irrigation Project	148,720 Acres	Montana Bul. 207
Valier Irrigation Project	160,000 "	Montana Bul. 217
Milk River Area	624,000 "	U.S.D.A. Series 1928—No. 32
Lower Flathead Area	300,160 "	U.S.D.A. Series 1929—No. 22
Gallatin Valley Area	480,000 "	U.S.D.A. Series 1931—No. 16
Lower Yellowstone Valley Area	262,400 "	(Not yet available)
Middle Yellowstone Valley Area	224,000 "	(Not yet available)

*Available reports may be obtained from the Montana Agricultural Experiment Station, Bozeman, Montana.

Detailed soil surveys, being more intensive than the reconnaissance surveys, are confined to irrigated and potentially irrigable land. Irrigated lands which have been covered by detailed soil surveys are shown in table 2.

Because of the very direct relation between the character and the quality of soils and the purposes for which land may be used, no important agricultural adjustment or development should be undertaken without giving primary or first consideration to a soil survey of the land area involved. Any agencies which ignore the results of a scientific soil survey in planning projects which involve irrigation development, resettlement, grazing districts, etc., are paving the way for a recurrence of the difficulties which they are now endeavoring to correct.

THE SELECTION AND DEVELOPMENT OF ADAPTED CROPS.—Once the soil surveyor has designated the soil types which are suited to crop production, the next step is to select the crops which are best adapted to the climatic conditions which prevail in the localities where the various soils have developed. Through a series of closely supervised experiments, the agronomists have determined the adaptability of many different kinds of crops and as a result of these studies many kinds have been recommended for use in Montana. It is significant that, of the important crops growing in Montana today, there are scarcely any the adaptability of which was not determined by the Experiment Station before they became widely distributed on farms.

Adaptation tests with numerous varieties and strains of alfalfa from many parts of the world resulted in the selection of Ladak, Grimm, and Cossack as the outstanding varieties for Montana producers of alfalfa.

The production of winter wheat in Montana has been stabilized materially through the development and distribution of Montana 36, Karmont, Newturk and Yogo. These were selected from among numerous varieties and strains because of high yields, excellent milling and baking qualities and ability to withstand the rigorous Montana winters.

A large number of spring wheats have been subjected to exhaustive tests for several years. As yet, no variety has been sufficiently consistent in superior performance over a period of years, as measured by yield and quality, to replace Marquis. This is especially true where back stem rust is not a factor affecting wheat yields.

Varieties of oats and barley which have been selected and

recommended for use on farms and ranches of Montana by the Agronomy Department are characterized by high yield, superior quality and disease resistance.

MAINTENANCE OF SOIL PRODUCTIVITY.—The maintenance of soil productivity, by preventing a decrease in its fertility and an increase in noxious weeds, is a problem of major importance in crop producing areas.

Results of crop rotation experiments under irrigation at Bozeman show definitely that a rotation which contains at least three successive years of alfalfa is capable of producing and maintaining high crop yields. The addition of manure regularly to one crop in the rotation has increased the yields of all crops. Furthermore, the adoption of rotations containing at least three successive years of alfalfa will prevent any noxious weeds from becoming sufficiently established to reduce crop yields or to interfere in any way with regular farm operations.

CROP IMPROVEMENT.—The crop production phase of agriculture is subject to changes which necessitate a definite program of crop improvement designed to produce strains to meet new situations. A breeding program involves the selection of parent material making various crosses in the hopes of effecting the desired combinations, and then several years devoted to selecting and testing the hybrid material to isolate superior strains. It is necessary to study thousands of hybrids in the nurseries to find a few desirable and superior selections that may later become commercial grains.

Since wheat is the leading cash crop in Montana, the Experiment Station plant breeders[2] are concentrating their attention on this crop. They are striving to produce new strains of winter wheat hardy enough to survive most winters with good stands on both irrigated and non-irrigated land, and at the same time to combine high yields with good milling and baking qualities and resistance to bunt or stinking smut. Characteristics sought in spring wheat are high yields, high quality, stiff straw, and resistance to diseases and drought.

A grass-improvment program[3] designed to improve grazing

[2]Wheat breeding at the Montana Agricultural Experiment Station is cooperative with the Division of Cereal Crops and Diseases, of the United States Department of Agriculture.

[3]In cooperation with the Division of Forage Crops and Diseases, United States Department of Agriculture.

for livestock is also in progress. Collections of various strains of some of the more promising native species have been assembled and are being compared with the hope of finding more desirable types of grasses for the range. The seed producing possibilities of the best grasses are being investigated in an effort to increase seed production and thus speed up the reseeding program.

CONTROLLING PERENNIAL WEEDS.—Investigation of methods of controlling perennial weeds found on Montana farms and ranches has produced information on weed control which has rather wide-spread application. These investigations have demonstrated conclusively that clean tillage is the most practical and economical method of cleaning up serious infestations of perennial weeds. Other studies prove that once the fields are clean, serious infestations are effectively prevented through rotation of crops which provides at least three consecutive years of alfalfa.

About 15 chemicals and herbicides have been tested to determine their value in killing Canada thistle, quack grass, wild morning glory or bind weed, white top and leafy spurge, when these infestations occur in inaccessible places.

RESEARCH IN ANIMAL HUSBANDRY

With millions of acres of land adapted only for grazing, adjustment programs designed to develop the agriculture of Montana on a more stable and profitable basis must provide a prominent place for the production of livestock.

Since 55 to 60 per cent of annual gross agricultural income of the State is derived from livestock and livestock products, it is logical that the Montana Agricultural Experiment Station should be actively engaged in the solution of the problems of livestock production and range management. The approach to the solution of these problems by the central station at Bozeman, and the various branch stations, is made through and under the supervision of at least nine research departments. These departments collectively conduct investigations into (1) the production, (2) prevention or protection, (3) economic, and (4) sociological phases of the problems of the livestock industry.

The production problems are a direct responsibility of the Animal Husbandry Department and the staff of this department is engaged in studies to determine the most economical

and efficient methods of breeding, feeding, and management of livestock, and the improvement of livestock products. Also, an effort is being made to discover the fundamental reasons why certain practices are more successful than others as an aid to their more general application in practical livestock production.

BEEF CATTLE INVESTIGATIONS.—The beef cattle investigations are conducted cooperatively with the North Montana Branch Station near Havre and the United States Range Livestock Experiment Station near Miles City where it is possible to study the problems of the cattlemen operating under range conditions.

A breeding herd of 150 good grade Hereford cows is maintained at the Havre Station with two objectives: (1) to determine whether the progeny of large, heavy boned, slow maturing, rangy type beef bulls will be as desirable cattle to raise and feed for the range country, as will the progeny of the smaller, earlier maturing, more compact type of bulls; and (2) to study the cumulative effect of continued breeding of large and small type bulls on the heifers and cows resulting from this breeding.

The facilities at the Station make it possible to conduct experiments on wintering cows, and to determine the influence of liberal and limited amounts of roughage fed during the winter period and the subsequent gains on summer range as it affects the development and growth of heifers to be used for breeding cows in range cattle production. This involves wintering of heifer calves, yearling heifers, and two-year-old heifers. A lease covering some 5000 acres of grazing land in the Bear Paw Mountains permits grazing experiments[4] with this herd of cattle during the summer to determine (1) the carrying capacity of the range; (2) the effects of over and under-grazing on the vegetation and the livestock; and (3) the best practices of range management.

A herd of approximately 700 Hereford cattle of excellent quaity are maintained by the State for experimental purposes at the United States Range Livestock Experiment Station near Miles City. Experiments with these cattle[5] handled under typical

[4]Cooperative with the Indian Service of the United States Department of Agriculture.

[5]Conducted under a cooperative agreement with the Bureau of Animal Industry of the United States Department of Agriculture.

range conditions include (1) record of performance studies to determine standards for selecting breeding animals instead of the present show ring records; (2) intensities of year-long grazing to determine utilization standards and carrying capacity of short grass ranges measured in terms of effect on breeding cows, supplemental feed required, and pounds of calf produced per cow, as well as the permanent welfare of the range; (3) wintering of cows and calves; and (4) work with feeder steers to determine the comparative merits of selling feeder steers as yearlings and as two-year-olds.

RANGE SHEEP INVESTIGATIONS.—A band of approximately 1700 high-grade Rambouillet ewes is maintained by the Montana Agricultural Experiment Station at the Fort Ellis Farm about three and one-half miles southeast of Bozeman and at the Bracket Creek Sheep Ranch near Clyde Park. This band of ewes with the annual lamb crop, is used in the investigation of some of the problems of handling sheep under range conditions.

An effort is being made to improve the mutton type and wool characteristics of Rambouillet sheep through careful selection and breeding. Accomplishment of this objective will result in greater income through the increased value to be derived from both the lamb and wool. Cross-breeding experiments now in progress indicate some possibility of improving range ewes for breeding purposes and of producing a higher percentage of grass-fat lambs at weaning time. Artificial insemination is being investigated with approximatey 500 ewes, to determine the possibilities of increasing the use of a particularly valuable sire in both purebred and range flocks. Management problems now being studied include (1) fattening lambs to determine the most efficient and economical use of Montana feeds, (2) study of minimum feed requirements for wintering ewes without decreasing lamb and wool production, and (3) methods of utilizing grazing lands to prevent deterioration of the forage cover and to build up the carrying capacity.

DAIRY CATTLE INVESTIGATIONS.—Research work with dairy cattle during the past year has been confined to a study of the value of dried molasses beet pulp as feed for dairy cows and dried beet pulp for growing dairy heifers. Beet pulp is an important

by-product of beet sugar production and is available in irrigated valleys where dairying is prominent.

HORSE INVESTIGATIONS.—This Station maintains approximately 175 head of horses at the Range Station near Miles City under a cooperative agreement with the United States Department of Agriculture. In addition to a breeding program to develop types of horses especially suited for western ranch and farm conditions, an intensive study of the physiology of reproduction is being conducted. The results of these studies will have immense practical value to the horse industry not only in Montana but throughout the nation.

RESEARCH IN BOTANY AND BACTERIOLOGY

The settlement of any agricultural area and the subsequent use of the land for the production of food for man and beast is accompanied by the introduction of numerous plant diseases and weeds. During any year, the residents of this State request information regarding the symptoms and control of diseases of plants grown in the home, greenhouses, gardens and fields, the identification and control of noxious weeds, the identification of poisonous and suspected-poisonous plants, the identification of fungi for food purposes, and numerous other questions of a more or less botanical nature.

The Botany and Bacteriology Department has been alert in checking on the prevalence and severity of important crop-plant diseases, and, to the limit of time and funds available, has conducted research to determine the most practical methods of control.

WHEAT SMUT.—Stinking smut or bunt of wheat is the most destructive plant disease in Montana. Over 30 chemicals recommended for controlling smut have been tested during the past ten years. Results indicate that bunt in winter wheat can be greatly reduced and in spring wheat can be practically eliminated by treating seed wheat with either two ounces of copper carbonate or one-half ounce of new improved Ceresan per bushel of grain.

Effectiveness of seed treatment for smut control in any locality may vary from year to year, since the main factors in smut development are soil temperature and soil moisture from the time the wheat germinates until it emerges.

BARBERRY ERADICATION AND BLACK STEM RUST OF WHEAT.—There are two possible sources of black stem rust in Montana: (1) the rust spores which develop from the cluster cup stage of this disease on the leaves of the harmful barberry bushes, and (2) the spores which blow into this State from rust-infected grains and grasses in the Southern States and Mexico.

Normally, the rust spores from the South arrive too late to cause much damage in this State; but occasionally, as in 1938, the prevailing moisture and temperature conditions may favor a rust epidemic.

The barberry bush serves not only as a source of early spring infection of rust, but also, on the leaves of this bush are developed new strains or crosses of the disease which may attack varieties of grain that heretofore may have proved resistant to stem rust.

The Botany and Bacteriology Department has been cooperating with the United States Department of Agriculture for several years in conducting a systematic program of locating and eradicating barberry bushes as a part of a permanent nation-wide program designed to control black stem rust of wheat and other cereals. Peculiar habits of growth of the barberry are such as to make this a long, tedious task and one to be pursued constantly if any benefit is to be derived from the work of preceding years.

ROOTROT OF WHEAT.—Within comparatively recent years, rootrot of wheat has become a serious disease. It is caused by a soil fungus which can attack all parts of the wheat plant, but the roots and stems are most commonly and seriously affected. Diseased plants are characterized by yellow leaves, stems brown at the base, and rotted brittle roots. The heads of badly diseased plants are poorly filled with shriveled kernels.

Control measures worked out by the Botany and Bacteriology Department for this State include the use of good seed treated with copper carbonate or new improved Ceresan, planting about September 15, and approved cultural practices.

FRUIT DISEASES.—An efficient and economical spray program for the control of scab on the McIntosh apple, an important commercial variety in Montana, was developed from investigations of the Botany and Bacteriology Department.

POTATO DISEASES.—The potato is an important cash crop in Montana, about 40,000 acres being planted each year. This crop is subject to several diseases including those caused by fungi and bacteria, serious physiological disturbances, and at least 16 different virus diseases. (See Bulletin 300.)

To assist potato growers in reducing losses, studies have been made and control methods recommended for field wilt, scab, rhizoctonia, black leg, storage-rot and the different virus diseases occurring in the State. (See Bulletin 231.)

PLANT HERBARIUM.—The herbarium assembled by the Botany and Bacteriology Department now contains about 35,000 specimens of flowering plants, 15,000 specimens of fungi and 3,000 specimens of mosses, etc.

These specimens are readily accessible for reference and study. They are especially useful in identifying plants discovered in vegetation surveys made in connection with the development of land-use programs.

RESEARCH IN CHEMISTRY AND METEOROLOGY

Chemistry occupies an important place in the business of producing, processing and utilizing agricultural products. The Chemistry Department contributes to the whole program of agricultural research by assisting various other departments of the Agricultural Experiment Station in obtaining a better understanding of the problems involved in the nutrition of plants and animals, the protection of plants and animals from diseases and insects, and the care, processing and utilizing of plant and animal products. The Department also assists many residents of the State directly by applying chemical knowledge obtained through miscellaneous experiments in the solution of agricultural problems.

Chemistry serves the livestock producers by determining the chemical composition of Montana feeds and forages. The chemist cooperates with the animal husbandman in determining the nutritive value and digestibility of feeds of various kinds. Such information is essential in the preparation of economical and efficient rations for various purposes. (See Bulletin 283.)

The location of phosphorus deficient soils in certain areas of the State indicates where the crops produced are likely to

be deficient in this important element and where phosphate fertilizers and suitable feed supplements may be used to advantage. (See Bulletin 316.)

Chemistry serves the plant producer by furnishing detailed information on the potential productivity of the soil as measured by the chemical composition. The growth and appearance of the growing plant combined with chemical studies of various parts of the plant while fresh and when dried are indicative of the availability of plant foods in the soil. A study of the plant and the soil at the same time offers possibilities of determining the causes of nutritional problems with a far greater degree of accuracy than an analysis of soil alone will reveal.

Chemical analyses of plant and animal specimens combined with like studies of soils and feeds respectively are enabling producers to secure larger yields and at the same time obtain quality in products which prove attractive in the markets and result in better prices. (See Bulletin 241.)

Miscellaneous chemical services include analyses of water to determine suitability for irrigation, of crops to determine presence of cyanide or prussic acid, of hay, grain, and straw to determine the suitability of feed after fields have been treated with arsenicals to control injurious insects, and of infertile soils to determine the cause of low crop yields. (See Bulletin 351.)

RESEARCH IN ENTOMOLOGY

Injurious insects present a constant menace to producers, processors, and consumers of agricultural products and are frequently a source of serious financial losses. Certain insects are the cause of direct injury to growing plants and to livestock. Other insects serve as carriers of plant and animal diseases capable of causing large financial losses. Still other insects may prove injurious to agricultural products either in processing, storage, or during the period of utilization.

The Entomology Department of the Agricultural Experiment Station renders an important service to agriculture through the investigation of numerous insect problems. Without this research, the agencies charged with the responsibility of applying the factual information in the control of insect outbreaks would be very seriously handicapped.

INSECT COLLECTIONS.—The systematic collection of injurious and beneficial insects is a continuous responsibility. The insects thus collected, with a card catalog and file of letters asking about insect pests, are of inestimable value in answering inquiries and in the prosecution of research projects.

INSECT SURVEYS.—Reliable forecasts of insect outbreaks of serious proportions are imperative if communities are to be prepared to apply effective control methods in time to prevent heavy losses. The Entomology Department provides a sound basis for these forecasts by conducting field surveys to determine the location and extent of insect infestations, and by gathering detailed climatic data for the area to determine any possible effects of the environment upon the survival.

LIFE HISTORY INVESTIGATIONS.—The effective control of any insect pest is impossible unless its life history is known. Thus, the Entomology Department devotes much time to detailed studies in the field and in the laboratory, following injurious insects through the various stages of their life history and determining the effects of variations in temperature, rainfall, humidity etc., upon their development. Finding the "weak spot" in the life history of any pest serves to direct further investigation to determine the most practical methods of control.

INVESTIGATION OF METHODS OF INSECT CONTROL.—In working out effective methods of controlling any injurious insect, the entomologist must of necessity cooperate very closely with every agency concerned with the agricultural product being damaged, from the beginning stages of production through to ultimate consumption. Thus the entomologist must study methods of control not only in the laboratory, but also in greenhouses and gardens; on farms and ranches; on cultivated land, abandoned land and native ranges; and in factories and warehouses.

Control methods must be effective and at the same time practical and economical if they are to be widely used.

SEED LABORATORY SERVICE AND RESEARCH

Important problems of crop production and marketing have engaged the attention of the staff of the Montana Grain Inspection Laboratory during the past twenty-four years. The duties now performed may be grouped under five headings; namely, (1) grain inspection and grading, (2) protein testing,

(3) milling and baking of wheat, (4) seed testing, and (5) seed inspection. Part of these duties are in the nature of direct service to residents of Montana who may send in questions pertaining to seed and grain testing. Another part of the duties is research which seeks to learn the underlying causes for the behavior of seeds in the laboratory and in the field, and the response of various varieties and types of wheat when milled and baked in different ways.

GRAIN GRADING.—Montana is a producer of high quality grain, the proper grading of which is of considerable commercial importance to both the producer and the consumer. The uniform application of Federal standards for inspection and grading of grains of various kinds through the years is of distinct benefit to Montana farmers in maintaining the quality of grain for which premium prices are paid.

PROTEIN TESTING.—The testing of wheat for protein content, begun by this Laboratory in 1925, continues to have an important place in the intelligent marketing of Montana's wheat crop. The sane use of the protein test by grain dealers and millers has done much to reflect back to the Montana producer the real value of his wheat crop and has enabled the millers to produce a much more satisfactory flour than would be possible without this information.

Research work on protein testing has assisted in developing proper methods of sampling the wheat for testing and aided in the interpretation of the resuts of the protein test.

MLLING AND BAKING STUDIES WITH WHEAT.—The milling value of a wheat is one of the important factors in determining its ultimate place in the wheat production program. The outstanding example is Marquis. This variety was recognized as early as 1914 to have exceptional milling and baking qualities, along with its other desirable characteristics. As new varieties are developed and evaluated as to ability to meet the changing demands, Marquis is frequently used as the measuring stick for quality.

An important function of the Laboratory is to test new varieties of wheat being developed for Montana and to interpret their properties in terms of their commercial value as bread wheats. Along with this phase of the research the effects of different tillage methods, crop sequences, and seasonal condi-

tions on quality of wheat for seed and flour making purposes are being studied.

SEED TESTING.—Laboratories are maintained in 46 of the 48 states in which the testing of agricultural seeds for germination and purity is an important part of their programs of work. That the seed producing and seed consuming public in Montana is deriving much benefit from these services in seed testing is shown by the fact that 2,544 samples of seed were tested in the Montana Laboratory during the year ending June 30, 1937. Samples of seed were tested for residents of all but 5 of the 56 counties.

The Montana Laboratory has made several important contributions to seed testing through research. A study of the treatment and plant producing value of "hard seeds" in legume seeds is perhaps the outstanding example. (See Bulletin 248.) The laboratory germination of seed of crested wheatgrass and western wheatgrass has been given special attention during recent years because the testing of the seed of these crops for germination presents certain problems not found in other closely related seeds.

SEED INSPECTION.—The Montana Seed Law seeks to protect the interests of both the producers and consumers of seed by charging the Montana Grain Inspection Laboratory with the responsiblity for the inspection of agricultural seed which is offered for sale within the State. The seed is sampled and examined carefully to determine if it is properly labeled. Cases of improper labeling are reported to the Commissioner of Agriculture, Labor, and Industry, who is responsible for enforcing the law.

Results of the annual seed inspection clearly indicate (1) the desirability of buying seed which is properly labeled and (2) the advisability of rechecking such seed as to its germination and the presence of noxious weed seeds.

RESEARCH IN HOME ECONOMICS

With the passage of the Purnell Act in 1925, the research programs of the Agricultural Experiment Stations were enlarged to include investigations of the problems of the rural home. This came about as a result of the growing feeling that the home was playing an important part in agriculture as a

producer and a consumer, and as a symbol of the satisfaction derived from labor. Therefore, any problem arising in the rural home would have some effect on agriculture.

As soon as the Purnell Fund became available (July 1, 1925) a department for home economics research was established at the Montana Agricultural Experiment Station. During the twelve years, this department has given its entire attention to the solution of problems related primarily to the homes of Montana.

FOOD AND NUTRITION.—Many of the questions arising in rural homes are concerned with the selection, preservation, and preparation of foods, so that they may furnish palatable and nutritious products. Nine studies comparing various methods of food preservation and preparation have been carried on, although not all have been completed. Potatoes, carrots, rutabagas, cabbage, and onions have been studied to determine the effect of winter storage on the palatability and vitamin content. Cool, damp storage for carrots and rutabagas, and warmer drier storage for potatoes resulted in palatable products and good retention of the vitamins. (See Bulletins 276, 277 and 346.)

Carrots, peas, sweet corn and string beans have been studied to determine the effect of canning by safe methods on the palatability and vitamin content. (See Circular 147.) Carrots canned in a pressure cooker retained less of their vitamin content than when well stored. (Bulletin 276.) Sweet corn canned in the pressure cooker, appeared to have lost considerable of its vitamin activity. (See Bulletin 347.)

Dried sweet corn, when cooked for table use, was desirable and retained more vitamin activity than when canned. Sweet corn preserved by salting was very palatable when cooked, and retained more vitamin activity than when canned. Fermented sweet corn when cooked was undesirable in flavor and low in vitimins B and C.

Experiments with various methods of cooking on the vitamin "C" content of potatoes showed that baked, steamed, and boiled potatoes retain the largest amounts of vitamin C, both in the fall and after winter storage. (Bulletin 346.)

In buying oranges, it has been found advantageous to purchase from the newest crop available, since their juice contains

much more vitamin C per given volume. Juice from a new crop of navel oranges contained over 50 per cent more vitamin C than the same amount of juice from Valencia oranges at the end of their season.

Quality and palatability of lamb is influenced by the feeds which the animals receive. Cooperative experiments with the Animal Husbandry Department show that when the concentrates in a fattening ration for lamb were varied, oats with alfalfa hay produced a meat that was slightly superior in quality, juiciness, and general desirability. (See Bulletin 320.)

Cooperative studies with the Agronomy Department are attempting to determine the quality of pastry flours made from white wheats grown in Montana.

TEXTILES AND CLOTHING.—The items of clothing purchased by the family are usually selected on the basis of cost, wearing quality, and appearance. Often, the wearing quality may be judged by a careful examination of the article, but this is not generally true in the purchase of silk hosiery. Since this item is rather important in a woman's clothing budget, a project dealing with the selection, care, and wearing quality of woman's silk hosiery was undertaken. Extensive textile and wearing tests on sixteen kinds of hose demonstrated that price is not a criterion for judging the wearing quality of hose, but instead, the weight of silk yarn used and the amount of twist in the yarn are important factors. Hose reinforced with cotton also wore better than those reinforced with silk. (See Bulletin 299.)

HOME MANAGEMENT.—The rural homemaker has many demands on her managerial ability. She usually has an especially wide variety of tasks to perform, both homemaking activities and some work connected with the farm. In addition, some farm women devote considerable time to community affairs. Along with this complicated pattern of activities, she must plan her expenditures and determine the quality of living of her family on the basis of a fluctuating income.

From 92 time records kept by rural women in various parts of the State, the Department of Home Economics has determined that the average time spent per week in all homemaking activities was 53 hours and 40 minutes, and in farm work, 9 hours and 10 minutes. This corresponds closely with results obtained

in similar studies in five other states. (See Bulletin 271.)

Forty rural families in 7 Montana counties kept accounts for one year to obtain data to answer the question—"What does it cost to live comfortably on the farm?" The study showed an average of 4.0 persons per family and the average total cost of living per year (excluding automobile, savings, and investments) was $1919. Compared with records from other states, these Montana rural homes ranked favorably as examples of a satisfactory quality of rural living. (See Bulleting 260.)

THE FAMILY.—A problem confronting many rural families living far from towns or in isolated localities is that of securing an education for their children. If the children must go away from home during the school year, the question of living arrangements is important. Therefore, a study of public school dormitories was made.

Information was gathered from 20 public school dormitories regarding their housing conditions and meal plans. From this information, recommendations were made for organizing and operating such dormitories in a satisfactory manner. (See Bulletin 201.)

Through the publication of the results of investigations and through replies to the many questions received from individual homemakers, the Home Economics Department has endeavored to render helpful assistance to all the homes of Montana, and thus contribute to the broad program of research in the State.

RESEARCH IN HORTICULTURE

The production of fruits and vegetables occupies an important place in Montana's agriculture. Residents of both rural and urban areas grow a wide variety of these crops primarily for home consumption. In some of the irrigated valleys considerable land is devoted to fruit and vegetable production for market.

The Department of Horticulture deals primarily with investigations of the more important problems of fruit and vegetable growers. In addition, this department renders an important service to the florists, nursery-men, landscape specialists, and home-owners generally by asisting with problems of home-beautification, through the planting of flowers, trees, shrubs, the establishment of lawns, and the planting of shelterbelts.

Some of the accomplishments which have practical application in Montana and elsewhere are as follows:

INFLUENCE OF PHOSPHORUS ON POTATOES.—The potato crop has responded to phosphorus applications wherever tried in Montana. In fact, the value of using phorphorus in improving the potato crop has been so striking that many growers are now applying phosphorus as a regular practice. The benefits of phosphorus when applied to the potato crop may be summarized as follows:

(a) Phosphorus encourages root development and starts the plants ahead of non-treated plants.
(b) Tuber set occurs earlier where phosphorus is used.
(c) Tuber set is generally increased.
(d) Total yield of potatoes is increased.
(e) A higher percentage of tubers are graded No. 1, thereby distinctly increasing profits.
(f) Maturity is improved and skin slipping is reduced, thereby improving appearance and values.
(g) A long potato, such as Netted Gem, fills out better at the ends, thus making a higher grade.
(h) The netting of the Netted Gem variety is heavier and more pronounced, which adds to the value of the grade.
(i) Less cracking occurs with the Bliss Triumph when phosphorus is used. This response of the potatoes is from applying the phosphorus by an attachment to the potato planter, which places the fertilizer as deep as the seed piece but a little to one side.

SEED POTATO IMPROVEMENT.—Because of the necessity for the elimination of potato diseases, tuber indexing as conducted by the Department of Horticulture of the Experiment Station has been the basis of seed potato improvement in Montana.

Marked improvement in seed stocks of potatoes has been made by selecting hills in the field, using the character of the vine, the yield, and the tuber type as indicators of desirable quality. These hills have then been indexed, using one tuber from each hill as an index. This method of indexing is highly efficient and gives maximum amounts of good seed stock with a minimum of indexing. This procedure when followed through, has reduced the amount of disease to a minimum and has been

adopted by many Montana potato growers in building up seed stocks.

The White Rose seed potato industry in Montana is entirely dependent upon tuber indexing. Many lots of potatoes were indexed in an effort to find a stock suitable for foundation seed. The present stock was finally built up from three tubers which were found by indexing to be disease free. Some 25,000 sacks of this variety now leave the State annually as seed stock for other regions.

Tuber indexing of seed stocks has value to all Montana producers of seed potatoes and must be recognized as being an important factor in putting and keeping Montana potato production on a dependable and profitable basis.

FERTILIZER TREATMENT OF VEGETABLE TRANSPLANTS.—Experiments with fertilizer and chemical treatments of soil for vegetable transplants, as well as variations of temperatures, have produced results which have outstanding value. This treatment of the transplant, irrespective of following field treatments, directly influences the field results, and shows that certain plant foods are especially desirable in the early stages of growth. Work with tomato and onion transplants showed material effects in the later development of these plants and has significantly increased the yields and improved the grade of the harvested crops, as summarized below:

(a) Potassium permanganate treatment of tomato transplants reduced fruit cracking 23 per cent.

(b) Nitrogen treatment increased the yield of tomatoes but increased blossom end rot disease by 97 per cent.

(c) Onion transplants grown at low temperatures, (53° to 60° F.) were superior to those produced under high temperatures. (60° to 70° F.)

(d) Onion transplants grown at high temperatures responded favorably to nitrogen fertilization, whereas those grown at low temperatures did not. The opposite was true with phosphorus.

(e) Both potassium permanganate and dextrose treatments resulted in a significant increase in the biological activity of the soil.

(f) The favorable responses to potassium permanganate may have been due to oxidation effects, the supply of manganese, or to the increased biological activity of the soil.

By carefully following the recommendations based on these experiments, transplants can be produced which are superior to those now commonly sold. Commerical growers may also increase their crop incomes materially through increased yields and/or improved quality.

The Horticultural Department at the central station at Bozeman, directs the horticultural studies in progress all over the State and is using the help in immediate charge and the facilities available at the Branch Station in the Bitterroot Valley in carrying forward the projects reported in detail under the Horticulture Branch Station, viz, the influence of fertilizers on the sweet cherry, the relation of growth to the fruiting of the apple, and investigations with vegetables.

RESEARCH IN IRRIGATION AND DRAINAGE

Irrigation farming has played an important part in the development of Montana's agriculture and has now reached the point where this State ranks fourth in the total acreage of land irrigated and eighth in total value of irrigated crops. Over 80 per cent of the irrigation development, from the standpoint of acres irrigated, has been on the initiative of the individual farmers and groups of farmers.

At present, not less than nine departments of the central station at Bozeman and two branch station are devoting considerable time to the solution of the problems which confront the farmers and ranchers who conduct a part, or all, of their farming on irrigated land.

During 1937, this Department concentrated its attention on four projects: (1) water power utilization with particular reference to home-made water lifting equipment; (2) methods of irrigating seed and canning peas; (3) study of water supply from Montana's watersheds, with special attention to irrigation, and (4) range improvement by water conservation.

HOME-MADE WATER LIFTING EQUIPMENT.—Bulletin 324 described a home-made centrifugal pump developed cooperatively by the Departments of Agricultural Engineering and of Irrrigation and

Drainage. The entire edition of this publication was exhausted within eight months. Since the bulletin was printed, further improvement was made in this home-made pump. (See Circular 150). It can be built at a low cost and when operated under low lifts up to 20 feet, has ample capacity for farm irrigation. Farm-built pumps of this type have developed capacities from 500 to 4000 gallons per minute varying with the size of the pump and the height of lift.

IRRIGATION OF PEAS.—The irrigation of peas has been studied cooperatively by the Departments of Botany and Bacteriology and Irrigation and Drainage to determine (a) what causes scalding of peas, (b) the effect of irrigation on the development of root rot and fusarium, and (c) what varieties are most susceptible to damage. Results obtained under the climatic and soil conditions governing these experiments show that early irrigation must be followed by frequent light applications of water. Fewer applications of water are necessary if the first irrigation is deferred until the peas are in full bloom. On well-drained soil, peas will tolerate liberal amounts of water, but the amounts at each application should be limited to that which can be absorbed within the root zone—to give large yields and good quality crop.

WATER SUPPLY FROM MONTANA WATERSHEDS.—Water supply studies conducted by this Department reveal that large volumes of water flow out of Montana each year without serving any useful purpose for agriculture, because the natural stream flow does not conform to the demand for water either for irrigation or power. Systematic and progressive reservoir construction on all streams sufficient to completely regulate and control the flow according to the demand for irrigation, power, or other uses is imperative if this State is to realize the full benefit from its water resources. (See Bulletin 353.)

IMPROVEMENT OF RANGE LANDS THROUGH WATER CONSERVATION.—That range lands may be greatly improved by the conservation and use of available water supplies is being shown by cooperative studies of the Departments of Agronomy and Irrigation and Drainage at the United States Range Livestock Experiment Station near Miles City. Runoff from range land, when spread and retained on the more level areas, can be made to produce much

extra feed for grazing or for hay. Conservation of these "run-away" waters also prevents soil erosion and reduces the silt problems along the main streams. From 25 to 75 acre-feet of water are lost every year per square mile of range land in central and eastern Montana. If properly controlled and used, this water would be capable of producing from fifty to one hundred tons of hay per section of land. Other studies show that, for best utilization of the forage resources on the range, it is necessary to provide stock water reservoirs, or to develop springs and wells at intervals of one to one and one-half miles.

In addition to the work on these four major projects, the Department of Irrigation and Drainage is making observations on several miscellaneous problems closely related to irrigation farming.

VETERINARY RESEARCH LABORATORY[6]

The possibility of serious losses through animal diseases and disorders necessitates an efficient veterinary service. Montana stockmen receive the benefits of three types of veterinary services. First, is the local veterinarian engaged in private practice. He is available for immediate call to diagnose the various diseases and disorders of all classes of livestock and to prescribe the remedies. Second, is the Montana Livestock Sanitary Board, charged with the responsibility of detecting, controlling and eradicating communicable diseases of livestock and protecting Montana stockmen against the introduction of such diseases from outside the State. The third type of service available to Montana stockmen is that rendered by the Veterinary Research Laboratory of the Agricultural Experiment Station. The investigations of this laboratory are devoted almost exclusively to the determination of the specific causes of major livestock diseases which occur in Montana and the development of effective remedies adapted to farm and ranch conditions in this State. The Veterinary Research Laboratory has

[6]The Montana Livestock Sanitary Board cooperates with the Montana Agricultural Experiment Station in conducting the investigations of the Veterinary Research Laboratory, This Laboratory has the guidance of an advisory committee consisting of Clyde McKee (Chairman), Dr. H. Marsh, and Dr. H Welch, Director, Veterinary Pathologist and Professor of Veterinary Science, respectively, of the Experiment Station; Dr. W. J. Butler, Executive Officer, Montana Livestock Sanitary Board; Dr. H. C. Gardiner, Montana Wool Growers Association; and Wallis Huidekoper, Montana Stock Growers Association.

made several notable contributions to veterinary knowledge, which have immense practical value to the producers of livestock in Montana. These contributions include among others:—

INTRADERMAL TEST FOR BOVINE TUBERCULOSIS.—In 1915, this Station published Bulletin 105 giving the results of the first investigations of the practicability of the intradermic test for tuberculosis, with special reference to range cattle. This study led to the adoption of the test described as official in Montana before it was recognized in other states.

HAIRLESSNESS AND GOITER IN NEW-BORN DOMESTIC ANIMALS.—This Station released information on hairless pigs and goiter which was of fundamental importance to the livestocok industry not only of Montana, but universally. The results of these investigations constituted the first recognition in farm animals of congenital goiter, the first recognition of the relation of hairlessness and weakness of new-born animals to thyroid deficiency, and the first development of the use of iodized salt for the prevention of these conditions.

PHOSPHATE DEFICIENCY IN CATTLE.—Bone chewing and skeletal weakness in cattle were determined to be definite indicators of phosphorus deficiency in the feed produced in large areas in Montana. As a result of these studies, the feeding of phosphates, usually in the form of bonemeal, mixed with the salt, has been popularized as a preventive.

BLACKLEG IN SHEEP.—Blackleg as a disease of sheep was demonstrated for the first time in the United States by the Montana Livestock Sanitary Board in 1919. In 1920, a cooperative study of this disease was started at Bozeman. In 1928, a complete report of this work was published in the Journal of the American Veterinary Medical Association.[7] As a result of this work, Blackleg is generally recognized as occurring in sheep, and heavy losses are now prevented by vaccination of sheep kept on heavily infected premises.

PROGRESSIVE PNEUMONIA OF SHEEP.— Investigation of "lunger disease" of sheep was started in 1922, in cooperation with the Montana Livestock Sanitary Board. Although this study is not yet completed, a large amount of information has been accumulated

[7]"Blackleg In Sheep"—Marsh, Welch and Jungher. Journal American Veterinary Medical Association, 74:63-88. December, 1928.

and advice of practical value has been released to sheep owners. There is definite evidence that the disease is not infectious; that there are no recoveries; and that it does not pay to retain a ewe in the flock after the first symptoms appear. Such ewes should be marketed while they still have mutton value.

INFECTIOUS ABORTION OF SHEEP.—In 1923, an infectious abortion in sheep caused by Vibrio Fetus was recognized by the Livestock Sanitary Board Laboratory as the cause of serious losses on a number of ranches. Since this organism had been reported in sheep only once before in the United States, a cooperative study was started at the Agricultural Experiment Station at Bozeman to study the disease. Animal experiments and field studies have made it possible to advise the sheep owner as to effective methods of control. It was found that the infection was not permanent in ewes, and the evidence is quite convincing that the disease usually may be prevented if the ewe is not permitted to use stagnant or semi-stagnant water during the period of pregnancy.

INTESTINAL PARASITES OF SHEEP.—Through observations and experimental work on intestinal parasites of sheep over a period of several years, this Laboratory has demonstrated that the parasitic worms causing the largest losses in Montana are species other than the Eastern Stomach Worm. The species of worms which are most injurious to sheep in Montana have been determined, and efficient methods of treatment have been developed and distributed to sheep owners. (See Circular 142).

PREVENTION OF NAVAL INFECTION.—An important contribution to disease prevention in young lambs has been the introduction of disinfection of the umbilical cord with tincture of iodine.

DYSENTERY OR WHITE SCOURS OF NEW-BORN LAMBS.—Ten years have been spent in making a thorough investigation of the fatal dysentery which occurs in new-born lambs under early shed-lambing conditions. The results of these studies have been reported in Bulletin 361 and Circular 153. These studies have definitely established the fact that this disease is the result of the activity of pathogenic strains of certain bacteria found in the intestines of all lambs. This disease occurs when the resistance of the lamb is lowered by exposure to cold and wet weather while at the same time a large number of bacteria are ingested by the lamb from the filth on the ewe and in the surroundings.

The control of dysentery of new-born lambs is fundamentally a sanitation problem, and the practical results of these findings are already in evidence in changes in the equipment and management of the lambing plants on the more progressive ranches.

ARTHRITIS IN LAMBS.—The investigation of a specific arthritis in lambs, started at the Laboratory of the Montana Livestock Sanitary Board and continued at the Agricultural Experiment Station, has established the facts that this disease was the result of infection with the bacillus of swine erysipelas[8] and that the bacteria gained entrance to the system through the navel at birth and through docking and castration wounds. Arthritis in lambs is now being prevented by disinfection of navels and by proper docking and castration methods which were determined experimentally by the Veterinary Research Laboratory.

FOOT-ROT IN SHEEP.—Controlled experiments with foot-rot in sheep led to the development of a practical and efficient treatment for use under Montana range conditions. The use of these findings under the supervision of the Livestock Sanitary Board is resulting in this disease being successfully controlled. (See Bulletin 285.)

MASTITIS IN EWES.—Large losses of ewes have resulted from mastitis, or "blue-bag", in the range flocks in Montana. Investigations at this Station have established the fact that this disease is a result of infection with a specific organism, a Pasteurella. Attempts to immunize against this disease have failed, but it has been demonstrated that the spread of mastitis or blue-bag in a band can be checked by bedding down in a new place every night.

BLACK DISEASE IN SHEEP.—Investigations have determined that serious losses of sheep in some farm flocks in the Bitteroot Valley are due to a disease described in Australia as "Black Disease". The Veterinary Research Laboratory has developed a vaccine which is effective in immunizing against the immediate bacterial infection which kills the sheep. This contribution makes it possible for sheepmen living in areas subject to Black Disease to remain in the sheep business.

CONTROL OF BANG'S DISEASE IN RANGE CATTLE.—Bang's Disease is being studied extensively in many laboratories, but very little

[8]"The Bacillus of Swine Erysipelas Associated with Arthritis in Lambs"—Marsh, Journal American Veterinary Medical Association, 78:57-63, January, 1931.

experimental work has been done with range cattle. Several lines of investigation on this disease have been recently undertaken, however, by the Veterinary Research Laboratory at this Station, with particular reference to range conditions. One important contribution of this work has been the development of a modification of the technique of the agglutination test[9] so that the test can be completed in the field within ten minutes after the blood is drawn and while the cattle are held in the chute. This eliminates individual identification of the animals and a second handling of the cattle, both of which are necessary when the Standard Laboratory Test is used. (See Circular 152.)

COCCIDIOSIS IN CATTLE.—Coccidiosis in cattle is a disease of major importance in the northwestern states. The work of this Laboratory shows that coccidia are normally present in the intestines of cattle and that clinical coccidiosis results in young animals under certain environmental conditions, such as sudden changes to feeds to which the cattle are not accustomed, thereby increasing their susceptibility to attack by the parasite. Practical control is obtained by handling calves during their first winter so that their resistance is always at a maximum. This laboratory also has developed a method of treating this disease which is now in general use.

[9]"A Whole-blood Field Agglutination Test for Bang's Disease in Range Cattle"—Welch and Marsh, Journal American Veterinary Medical Association, 86:493-507. Journal Article No. 45, Montana Agricultural Experiment Station, April, 1935.

BRANCH STATION INVESTIGATIONS

THE HORTICULTURE BRANCH STATION

Experimental work conducted at this Station, located near Corvallis in the Bitterroot Valley, assists materially in solving some of the serious production problems of the fruit and vegetable growers in western Montana. These studies also serve as an additional check on the results of investigations conducted by the Horticulture Department at Bozeman.

INVESTIGATION OF SWEET CHERRY PROBLEMS.—Early bearing of young sweet cherry orchards and maturity of the trees in the fall is directly influenced by orchard practices. In test orchards located on the east shore of Flathead Lake which are supervised by the Department of Horticulture, careful observations disclosed the fact that 94.4 per cent of the three-year-old cherry trees with a cover crop of alfalfa produced a good set of fruit spurs and fruit buds, while only one-half per cent of the trees of the same age which were clean cultivated showed any fruit spurs and fruit buds and the set was light.

Observations of sweet cherries under clean cultivation and with alfalfa as a permanent crop indicate that the group of trees in alfalfa will be in good bearing several years in advance of those trees which were kept cleanly cultivated. The sets of fruit spurs and fruit buds on trees growing in alfalfa were nearly double those observed on trees kept cleanly cultivated. The addition of boron and phosphorus increased the spur set distinctly on the clean cultivated trees. In fact, the heaviest spur set in both alfalfa and clean cultivation plots occurred with the boron treatment. Alfalfa also hastens the maturity of the trees in the fall and thereby brings about greater resistance to winter injury.

"DROUGHT SPOT" IN APPLES.—"Drought Spot" has caused serious damage to the apple crop in some orchards in the Bitterroot Valley. Experiments conducted by the Department of Horticulture in test orchards showed that the first application of boron not only greatly reduced the damage from drought spot, but also materially improved the color of the apples. The use of cover crops and the addition of manure in orchards also re-

duced the amount of drought spot injury. The combination of cover cropping and boron application gave greater benefits than either used alone.

EFFECTS OF PHOSPHATE FERTILIZER ON VEGETABLE CROPS.—Very significant improvement in yield and grade of vegetable crops has resulted from applying phosphate fertilizers, and the time of maturity for the crop has been distinctly changed and generally advanced. Head lettuce is generally ready for harvest a week to ten days earlier than the non-phosphated crops, and tomatoes will produce the first ripe fruit at an earlier date.

Phosphates have been applied to the vegetable crop in bands on either side of the seeded row, the fertilizer being put into the root zone. Desirable results have been obtained by applying as low as 125 pounds of treble superphosphate to an acre, or its equivalent of 375 to 400 pounds of superphosphate.

While much further study is necessary the nutritional work as carried thus far demonstrates definitely that substantial financial gains can be made by commerical vegetable growers in Montana through the use of phosphate fertilizers. The Horticulture Branch Station is not alone getting valuable information concerning the problems of the fruit and vegetable growers of western Montana, but the Superintendent is active in studying more general problems, particularly those relating to the use of water and the advantages of irrigation.

At the Horticulture Branch Station special studies are undertaken to help solve the fruit and vegetable problems peculiar to this region of the State, but the facilities are also used to broaden our knowledge of problems having a more state-wide application. Following this policy, projects concerned with potato fertilization, potato improvement, and other studies with transplants, which are reported under the Horticultural Department at Bozeman, are also being studied at the Branch Station.

THE HUNTLEY BRANCH STATION

All experimental work at this Station is cooperative with various Bureaus of the United States Department of Agriculture. Experiments concentrate on the production of both irrigated and non-irrigated field crops, dairying and lamb feeding.

IRRIGATED ROTATIONS.—It is generally recognized that a successful irrigated agriculture requires a system of farm manage-

ment that will maintain yields at comparatively high levels. Experimental evidence and the experience of farmers indicate that this may be accomplished by the adoption of a more or less definite system of crop rotation which includes legumes such as alfalfa, barnyard manure, and in some cases commercial fertilizers.

Experiments at the Huntley Station prove the folly of continuous cropping and at the same time emphasize the distinct advantages of producing sugar beets in a system of cropping which makes generous use of alfalfa, and provides for regular applications of barnyard manure and phosphate fertilizers.

MAXIMUM CROP PRODUCING CAPACITY OF SOILS.—The soils of the Yellowstone Valley near Huntley are capable of much higher average production under irrigation than is being obtained at present. By combining the best practices observed in previous experiments, including rotation with alfalfa and applications of manure and commercial fertilizers, crop yields may be increased materially and maintained at high levels. The average acre yields over a 12-year period in the maximum crop yield experiment were as follows: alfalfa, (2nd year)—7.01 tons; alfalfa, (3rd year)—6.54 tons; corn—72.6 bushels; oats—98.9 bushels; beans—48.8 bushels; potatoes—464.6 bushels; sugar beets—20.9 tons, and spring wheat—54.1 bushels.

DRY-LAND CULTURAL OPERATIONS.—Comparison of different methods of tillage on non-irrigated land during the past twenty-five years furnishes proof that plowing when the soil is in good condition to plow is more important than the time of year in which the work is done. Fall plowing should generally be left rough to prevent erosion by wind and retard run-off. Fall or spring plowing for fallow have consistently outyielded fallow plowed in late June or July.

DRY-LAND CROP ROTATIONS.—On non-irrigated land at this Station, the most satisfactory crop rotation provides a cash crop such as wheat, a feed crop such as oats, barley or corn, a weed-control practice such as clean fallow or cultivated crop, and a moisture storage practice such as fallow, and to a lesser extent corn production. The use of barnyard manure and green manure crops has not increased crop yields.

FORAGE CROPS ON THE DRY-LAND FARM.—Forage crops for the maintenance of livestock should occupy an important place in a well-balanced system of dry-land agriculture. Early amber sorgo, corn, sudan grass, and alfalfa have produced satisfactory yields. Winter rye, peas, sudan grass, soybeans, sorgo and corn, grazed in the order named, have provided palatable feed for hogs from early May until the first of October.

DAIRY CATTLE BREEDING.—The greatest problem of the dairyman is the selection of his sire. During the past nineteen years, a comparison of daughters' and dams' production records in the Station herd show that the level of production may be maintained and increased if "proved" sires are used continuously.

DAIRY CATTLE FEEDING AND MANAGEMENT.—Dairymen are also interested in feeding practices which result in economical production of butterfat. During the past fifteen years, the Huntley Station has conducted experimental work to determine the producing ability of dairy cows when fed different feeds, especially roughages commonly grown on irrigated farms in that vicinity. It is significant that cows which have been fed rations consisting wholly of roughages during entire lactation periods, have been able to consume consistently large amounts of this kind of feed and produce good yields of milk and butterfat.

IRRIGATED PASTURES.—Experiments conducted at the Huntley Station furnish ample proof of the importance of tame grass pastures on irrigated farms. One acre of irrigated land planted with the Huntley pasture mixture will provide sufficient grazing to carry from 1½ to 2 cows each summer for a period of five months, thus effecting a saving of about five tons of alfalfa hay compared to feeding the cows in a dry-lot.

LAMB FEEDING EXPERIMENTS.—Experiments conducted at the Huntley Station over a period of six years have demonstrated the value of locally grown feeds, including grain and sugar beet by-products in finishing lambs for market. Locally grown irrigated oats when fed with wet beet pulp and alfalfa hay are superior to other grains for this purpose. Local feeders are applying the results of these experiments; and in beet growing sections of the state, the home-grown feeds have to a large extent, replaced corn which was formerly shipped in from the Corn Belt for fattening lambs.

JUDITH BASIN BRANCH STATION

Located in the Judith Basin about 1½ miles west of Moccasin, at an elevation of 4,300 feet, this Station serves the higher non-irrigated bench lands of the State. The experimental work is concentrated on the problems relating to the production of small grains, forage crops including dry-land pastures, shelter belts, and gardens. Careful observations over a period of thirty years are sufficiently conclusive to serve as a sound basis for recommendations as to agricultural adjustments that are much needed in the Judith Basin and in other similar areas.

CULTURAL METHODS FOR SMALL GRAINS.—Results of experiments with crop rotation and tillage methods prove rather definitely that only fine textured soils, which have sufficient depth to respond to moisture conservation methods such as summer fallow, are sufficiently productive to justify their use for wheat and other small grains. Additional data are available on recommended varieties, methods of seed-bed preparation, and dates, rates and methods of seeding which will enable farmers to obtain maximum yields in localities where wheat may be grown. The importance of the furrow drill now so generally used for seeding winter wheat in central Montana was first demonstrated in Montana by the Judith Basin Branch Station.

REGRASSING ABANDONED CROP LAND.—Outstanding results with forage crops, especially perennial grasses, serve to emphasize the fact that grass must eventually occupy a more prominent position in the agricultural program of this part of the State.

The raising of wheat and other grains on submarginal land has been discontinued to such an extent, not only in central Montana, but in many other parts of the State, that the regrassing of this abandoned crop land has become one of the major problems of agricultural adjustment. The Judith Basin Branch Station has made a major contribution toward the solution of this problem by proving the adaptability of crested wheatgrass to Montana and by developing seeding practices whereby stands of this grass may be established economically. Many farmers now have excellent stands of crested wheatgrass by applying the methods of seeding recommended by this Station.

CRESTED WHEATGRASS PASTURES.—An experiment with non-irrigated grass pastures at the Judith Basin Branch Station has

attracted unusual attention throughout the Northern Great Plains. Crested wheatgrass and brome grass, seeded in 1932, were grazed in comparison with native grass during 1934, 1935, 1936, and 1937, under rainfall conditions which were far below average. The results from crested wheatgrass were phenomenal. For these four years, a crested wheatgrass pasture of 23.6 acres produced each year an average of 592 days of grazing while the same area of native grass furnished an average of 224 pasture days. Measured in terms of beef, the crested wheatgrass produced 50.2 pounds of beef per acre annually while the native grass during the same years averaged only 19.9 pounds of beef per acre.

DRY-LAND FORAGE CROPS.—If livestock is to be given a larger place in the agriculture of central Montana, the production of forage for wintering and for use in emergencies must be given more consideration. Experiments at this Station emphasize the value of corn for fodder, spring rye and oats for hay among the annuals, and of alfalfa as a perennial forage crop of exceptional merit. Sweet clover also fills an important place both for hay and pasture.

SHELTERBELT INVESTIGATIONS.—A visit to the Judith Basin Branch Station will furnish conclusive proof of the very practical benefits to be derived from a shelterbelt. Not only does the shelterbelt improve the attractiveness of the farm or ranch home, but it adds greatly to the comfort of man and animals by protection from winds and drifting soil and snow. It has survived the recent dry, hot seasons.

Sherterbelt plantings at this Station have demonstrated the dependability of the Siberian Pea-tree, (also called Caragana) in central Montana. It is very drought-resistant and winter hardy, and is one of the easiest shrubs to establish.

THE NORTH MONTANA BRANCH STATION

This Station is located in Hill County, approximately 8 miles southwest of Havre, at an elevation of 2,600 feet. Results obtained from the research projects are applicable generally throughout the plains area of northern Montana. The investigational work is concerned with two groups of problems: (1) those dealing with fudamental principles of crop production and soil management, particularly as they may apply to small grains

and forage crops; and (2) those related to the production of beef cattle under range conditions. It is significant that many fundamental recommendations, based upon results of experiments conducted at this Station, are now being used by successful farmers. Station data are also widely employed by various agencies as a sound basis for adjustments designed to bring about the use of agricultural practices adapted to the soil and climate of this area.

DRY-LAND TILLAGE METHODS AND CROP ROTATIONS.—Field experiments are conducted to furnish information on tillage practices and crop sequence best suited to Montana soil and climatic conditions. From 1926 to 1937, May-plowed fallow has averaged 16.6 bushels of Marquis wheat per acre as compared with 14.3 bushels from plowless fallow. The advantages and disadvantages of various tillage practices are carefully worked out to assist in the proper application of the results under farm conditions.

Careful observations for twenty-one years have helped to correct certain popular yet erroneous ideas about crop rotations on the non-irrigated farm. For example, green manure in a regular rotation on dry land fails to give the response usually obtained in the more humid sections or under irrigation. Field investigations have shown that continuous corn has marked advantage in productivity of fodder and shelled corn as compared with corn grown on plowed stubble after small grains. The favorable yields from continuous cropping with certain intertilled crops is an interesting feature of the work at this Station.

RECLAIMING ABANDONED CROP LAND.—The reclamation of abandoned crop land by fall seeding of crested wheatgrass is an important contribution. The fact that no cultivation is needed and that the grass may be successfully established by sowing at a thin rate with an ordinary grain drill directly in the stubble or weeds, indicates a highly practical and economical method of regrassing these dry areas in a relatively few years, which otherwise would require several decades to accomplish. Native species are now being tested to determine the possibility of their use in regrassing. No evidence is yet available that the unplowed range can be seeded by this method.

CEREAL VARIETIES RECOMMENDED.—Field experiments at this Station have proved the adaptability to the northern Montana

environment of certain standard varieties of the leading small grains, and they furnish a sound basis for recommending to Montana dry-land farmers such varieties as Ladak alfalfa, Horn barley, Idamine oats, Prolific spring rye, Marquis, Reward, and Ceres spring wheat, and Dakold winter rye. The recent breeding program has produced materials from which there is considerable promise of selecting a yet better spring wheat for Montana.

SOURCE OF PURE SEED.—The North Montana Branch Station has the responsibility of maintaining a supply of foundation seed of certain standard varieties. These supplies of seed are distributed by the Montana Extension Service through the Montana Seed Growers Association. With this arrangement a reliable source of pure seed of the important commercial varieties is always available. This Station has released at various times foundation seed of Marquis spring wheat, Prolific spring rye, Dakold winter rye, Markton oats, Horn barley, Ladak alfalfa, and the standard strain of crested wheatgrass.

WEATHER CONDITIONS AND CROP YIELDS.—This Station has made an important contribution to the task of adjusting Montana's agriculture to a Great Plains environment through a study of the relationship between various climatic factors and the yields of grains and forages. These investigations have shown that numerous rainfall and temperature reactions are involved, all of which have an important influence upon crops grown either for seed or forage. Early seasonal moisture has much to do with the grain yield of wheat, oats, and barley. Many climatic factors, predisposing to good or poor yields apparently become operative previous to the time of heading. With reference to forage production, the proper distribution of rainfall and equable temperatures seems necessary if maximum yields are to be harvested. These studies have been used to assist in formulating a sound philosophy of land utilization for the district served by this Station.

LIVESTOCK INVESTIGATIONS.—Investigations with livestock, involving cattle and hogs, were designed for utilizing locally produced grains and forages and covered several angles of winter feeding and fattening. Important contributions of this Station to the producers of livestock include: (1) successful finishing of hogs on rye alone and in combination with other grains,

(2) the satisfactory use of winter rye hay and spring rye hay for maintaining beef cattle through the winter season, (3) the use of wheat of low market value as a fattening grain for hogs and cattle, (4) the development and refinement of Montana's plan of baby beef production, (5) by the use of large and small type sires (many points relative to the economic efficiency of herds representative of each type are now being worked out), and (6) feeding cows on liberal and restricted plans of nutrition, to investigate the effect on the calves and the mature animals.

THE UNITED STATES RANGE LIVESTOCK EXPERIMENT STATION

To study the problems of the range livestock industry in a manner which will appeal to practical stockmen, requires: (1) a range environment, (2) adequate numbers of range livestock, and (3) range-minded investigators. The United States Range Livestock Experiment Station near Miles City provides facilities for studying range livestock problems which are not available in any other state. By way of range environment, the United States Department of Agriculture provides approximately 57,000 acres of grazing land typical or characteristic of much of the short-grass grazing land of eastern and southeastern Montana, an area sufficient to provide year-round grazing. The Montana Agricultural Experiment Station has made available approximately 700 Hereford cattle of good breeding and 175 horses of the draft and saddle types. The United States Department of Agriculture furnishes sheep for a grazing exepriment. The Department also provides the staff of investigators—men who have received special technical training for the positions they hold. Supervision of all research projects is exercised jointly by representatives of the Animal Husbandry Department of the Montana Station and the Bureau of Animal Industry of the U. S. D. A. Present investigations of interest to cattlemen include: (1) a record-of-performance project in which the steer calves from three herds of registered cows, each headed by a different bull, are individually stall-fed on corn, dry beet pulp and alfalfa hay to 900 pounds and the results measured in terms of feed consumed per 100 pounds of gain, in carcass yield and in tenderness and palatability of the meat, (the objective is to develop

a more reliable plan of selecting breeding animals than the present show ring performance); (2) wintering of beef calves—a project to determine the effect on subsequent growth and development of suckling calves, of summer treatment with their dams on three different planes of nutrition or intensities of grazing; (3) methods of wintering beef cows on the range—a project including two herds of breeding cows to determine the economy of using a limited high protein supplement or a limited ration of alfalfa hay upon the maintenance of breeding cows and on the relative number and quality of the subsequent calf crop; (4) feeder steer experiment—to determine the comparative merits of selling feeder steers as yearlings and as two-year-olds; (5) grazing experiment—involving three lots of breeding cows carried on year-long grazing on three intensities of use, to determine utilization standards and carrying capacity on short grass ranges, as measured in terms of effect on breeding cows, supplemental feed required, and pounds of calf produced per cow, as well as the permanent welfare of the range. This project involves cooperation between the Bureaus of Animal Industry and of Forest Service of the U. S. D. A. and the Montana Station.

Sheep at the United States Range Station are used in an experiment which provides for grazing at five degrees of forage utilization. Such a study will furnish reliable information on the reaction of the sheep and the range vegetation to the variation in rates of stocking the pastures.

The work with horses at the United States Range Station has two major objectives at present: (1) breeding to produce types of horses especially suited for western ranches and farms, and (2) determination of the reason why large numbers of mares fail to produce colts. The latter objective involves very detailed, as well as fundamental studies, of the physiology of reproduction.

GENERAL INFORMATION

COOPERATIVE RELATIONSHIPS

Research cannot serve agriculture economically nor efficiently unless the research program presents a coordinated attack on the problems to be solved. Such an approach to the solution of the problems of agriculture is possible only through effective cooperation of all agencies concerned.

The progress made by the Montana Station in agricultural research has been due in a large measure (1) to the fine spirit of cooperation within the organization, and (2) to the cooperation of numerous Federal, State, and private agencies. During the year, cooperative relationships have been maintained through both formal and informal agreements with a large number of agencies, whereby agricultural research in Montana receives the benefits of financial aid and technical assistance above what is possible by direct legislative appropriations.

Among the agencies which cooperate with the Montana Agricultural Experiment Station are the United States Department of Agriculture, the United States Department of Interior, the Farm Credit Administration, Tennessee Valley Authority, Works Progress Administration, National Youth Administration, National Resources Committee, Montana State Department of Agriculture, Labor and Industry; Montana Livestock Sanitary Board, Anaconda Copper Mining Company, and the Agricultural Experiment Stations of nearby states. Among the various branches of the United States Department of Agriculture which cooperate with the Montana Station are included the Agricultural Adjustment Administration, the Farm Security Administration, the Soil Conservation Service, the Forest Service, and the Bureaus of Agricultural Economics, Animal Industry, Chemistry and Soils, Dairy Industry, Entomology and Plant Quarantine, Plant Industry, and the Weather Bureau.

PUBLICATIONS

From time to time, research departments assemble and analyze the results of their investigations. This information, with

suitable interpretations, is published as bulletins and circulars for general distribution, and as mimeographed circulars and special journal articles for a more limited mailing list. A printed list of available publications[10] may be obtained upon request.

During the period December, 1936—November, 1937, the publications of the Montana Station include twenty-one bulletins, two circulars, four mimeographed circulars, and ten technical papers, as follows:

BULLETINS:

No. 330. An analysis of Agriculture on the Valier Irrigation Project. P. L. Slagsvold. 2000 copies, 48 pages.

No. 331. Analyses of Commerical Fertilizers. Edmund Burke and Mr. Bruce. 1000 copies, 12 pages.

No. 332. Soil Survey of Teton County. L. F. Gieseker. 2000 copies, 64 pages.

No. 333. Montana Insect Pests for 1935 and 1936. A. L. Strand. 2500 copies, 40 pages.

No. 334. Phosphate Investigations in Montana, 1936. Jesse R. Green. 3000 copies, 22 pages.

No. 335. Soybeans in Montana. A. H. Post. 3000 copies, 11 pages.

No. 336. The Effect of Tillage Method, Crop Sequence and Date of Seeding upon the Yield and Quality of Cereals and Other Crops Grown Under Dry Land Conditions in North Central Montana. M. A. Bell. 3000 copies, 128 pages.

No. 337. Soil Survey of Cascade County. L. F. Gieseker. 2000 copies, 66 pages.

No. 338. Production Requirements and Costs of Irrigated Farms in Montana. P. L. Slagsvold and Clyde Howard. 3000 copies, 36 pages.

No. 339. Tests of the Use of Rubber Tires and Steel Wheels on a Farm Tractor. H. E. Murdock. 4000 copies, 36 pages.

No. 340. Crop Regions in Montana as Related to Selected Environmental Factors. L. P. Reitz. 4000 copies, 84 pages.

[10]Montana residents may obtain the publications of this Station without cost by writing to the Library-Publications Department, Montana Agricultural Experiment Station, Bozeman, Montana, and indicating the number and title of the publication desired, or by applying to the Agricultural Extension Agent of your county. The Station will gladly place your name on the mailing list to receive the publications of special interest as issued.

No. 341. Cattle Ranching in Montana, M. H. Saunderson and D. W. Chittenden. 4000 copies, 32 pages.

No. 342. Analysis of the Huntley Irrigation Project. P. L. Slagsvold. 3000 copies, 20 pages.

No. 343. The Relief Problem in Montana. C. F. Kraenzel. 3500 copies, 64 pages.

No. 344. A Study of the Operation of Tractors and Implements Under Farm Conditions. H. E. Murdock. 3000 copies, 102 pages.

No. 345. An Analysis of Montana Farm Prices. P. L. Slagsvold. 3000 copies, 80 pages.

No. 346. The Effect of Winter Storage on the Palatability and Vitamin Content of Potatoes Grown in Montana. Helen Mayfield, Jessie E. Richardson, Ruth Davis, and Erlene J. Andes. 4000 copies, 23 pages.

No. 347. The Effect of Home Preservation on the Quality and Vitamin Content of Golden Bantam Sweet Corn. Jessie E. Richardson, Helen Mayfield, and Ruth Davis. 4000 copies, 22 pages.

No. 348. Assessment of Montana Farm Lands. R. R. Renne and H. H. Lord. 3500 copies, 56 pages.

No. 349. Soils of Judith Basin County. L. F. Gieseker. 2000 copies, 55 pages.

No. 350. The Conservation of Montana's Irrigated Lands. P. L. Slagsvold and H. H. Lord. 4000 copies, 32 pages.

CIRCULARS:

No. 150. The Homemade Centrigufal Pump. O. W. Monson and H. E. Murdock. 4000 copies, 20 pages.

No. 151. Some Montana Birds: Their Relation to Insects and Rodents. H. B. Mills. 3000 copies, 48 pages.

MIMEOGRAPHED CIRCULARS:

No. 1. Financial Facts of Montana Counties. R. R. Renne. 12 pages.

(New Series)

No. 1. Use of Standard Reference Material in Vitamin A and B_1 Bio-Assay. Jessie E. Richardson and Helen L. Mayfield. 13 pages.

No. 2. Regulations for Seed Testing at the Montana Grain Inspection Laboratory. W. O. Whitcomb. 11 pages.

No. 3. An Analysis of Montana Production Credit Association Loans. (With the Assistance of W. P. A.) R. R. Renne. 14 pages.

TECHNICAL PAPERS:

A Sporadic Wheat Pest in Montana. G. Allen Mail. Journal of Economic Entomology; Vol. 30, August 1937, Pp. 670-675. (Journal Series No. 80.)

Breaking the Dormancy in the Sugar Beet Webworm (L. strictalis L.) by Means of Chemicals. J. H. Pepper. Journal of Economic Entomology; Vol. 30, April 1937, Pp. 380. (Journal Series No. 85.)

Some Observations on Grylloblatta Campodeiformis Walker. H. B. Mills and J. H. Pepper. Annals of the Entomological Society of America; Vol. 30 (1937), Pp. 269-275. (Journal Series No. 86.)

Some Observations on the Vitamin C Content of Oranges and Lemons. Jessie E. Richardson, Ruth Davis and Phyllis Sullivan. Food Research; 1937, Vol. 2, No. 1. (Journal Series No. 89.)

The Vitamin C Content of Potatoes Prepared for Table Use by the Various Methods of Cooking. Jessie E. Richardson, Ruth Davis and Helen L. Mayfield. Food Research; 1937, Vol. 2, No. 1 (Journal Series No. 90.)

Sclerotium Blight of Wheat. P. A. Young. Phytopathology; Vol. 27, Pp. 1113-1118. November 1937. (Journal Series No. 91.)

Oven Spring of Dough as Correlated with Certain Properties of Bread. W. O. Whitcomb. For meeting of Cereal Chemists in Minneapolis, May 24-28, 1937. (Journal Series No. 93.)

Measurement and Correction of Assessment Inequalities on Agricultural Lands. R. R. Renne and H. H. Lord. Journal of Farm Economics; Vol. XIX, No. 4, November 1937, Pp. 926-934. (Journal Series No. 94.)

An Appraisal of Farm Land Assessments. R. R. Renne and H. H. Lord. Journal of Land and Public Utility Economics; Vol. 13, No. 4, Pp. 360-371. (Journal Series No. 95.)

Stomatitis in Young Lambs Involving B. Necrophorus and Virus of Contagious Ecthyma. H. Marsh and E. A. Tunnicliff. Journal of the American Veterinary Medical Association; Vol. 91, New Series V. 44, November 1937, Pp. 600-605. (Journal Series No. 97.)

CHANGES IN STATION STAFF

Dr. A. L. Strand, formerly Head of the Department of Entomology of this Station, was promoted to the presidency of Montana State College to succeed Dr. Alfred Atkinson who resigned on September 1, 1937. Effective on the same date, F. B. Linfield retired from active administrative duties as Director of this Station after having served in that capacity for a period of thirty-three years. He will continue to serve the Experiment Station as Director Emeritus and Head of the Department of Library and Publications. Clyde McKee, for sixteen years Head of the Agronomy Department of this Station, was appointed as Director Linfield's successor. Professor A. H. Post, a member of the Agronomy Department of the Montana Station for thirteen years succeeded Clyde McKee as Agronomist.

Resignations: Resignations from the Station include: I. E. Broaddus, Experiment Station Clerk; Kenneth J. Goering, Assistant in Chemistry; Mary L. Haskins, Bulletin Editor; G. Allen Mail, Assistant Entomologist; J. L. Sutherland, Superintendent of Judith Basin Branch Station; and A. H. Walker, Assistant Animal Husbandman.

Appointments: New appointments to the Station staff include: R. H. Bamberg, Associate Agronomist; Dr. R. T. Clark, Assistant Animal Husbandman; Margaret Dewey, Bulletin Editor; Louise Eager, Secretary to Director; Ruth S. Haggerty, Assistant in Home Economics; Dr. H. B. Mills, Head of the Entomology Department; Donald J. Pletsch, Assistant Entomologist; L. P. Reitz, Assistant Agronomist; S. B. Speck, Assistant in Chemistry; Dr. E. J. Wellhausen, Associate Agronomist.

ORGANIZATION OF THE EXPERIMENT STATION[11]

MONTANA STATE BOARD OF EDUCATION

Roy E. Ayers, Governor		Ex-officio, President	
Harrison J. Freebourn, Attorney General		Ex-officio	
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P. S. ECKERT, B.S., Asst. in Agrl .Econ.

AGRONOMY
A. H. POST, M.S., Head
R. H. BAMBERG,[12] Ph.D., Assoc. Agron.
L. F. GIESEKER, M.S., Assoc. Agron.
E. J. WELLHAUSEN, Ph.D.,Assoc. Agron.
F. K. NUNNS, M.S., Asst. Agron.
L. P. REITZ,[12] M.S., Asst. Agron.
WM. B. NELSON, B.S., Asst. in Agron.

ANIMAL HUSBANDRY
D. W. CHITTENDEN, M.S., Head
R. T. CLARK, Ph.D., Animal Geneticist.
E. R. McCALL, M.S., Asst. An. Husb.

BOTANY AND BACTERIOLOGY
H. E. MORRIS, M.S., Head
M. M. AFANASIEV, Ph.D., Asst. Botanist

CHEMISTRY AND METEOROLOGY
EDMUND BURKE, B.S., Head
F. T. DONALDSON, Ph.D., Asst. Chem.
J. R. GREEN, M.S., Assistant Chemist.
S. B. SPECK, B.S., Asst. in Chemistry

ENTOMOLOGY
H. B. MILLS, PhD., Head
J. H. PEPPER, M.S., Asst. Ent.
D .J. PLETSCH, M.S., Asst. Ent.

GRAIN LABORATORY
A. H. POST, M.S., Director.
W. O. WHITCOMB, M.S., Supt.
W. D. HAY, M.S., Seed Analyst.

HOME ECONOMICS
JESSIE E. RICHARDSON, Ph.D., Head
HELEN L. MAYFIELD, M.S., Asst. H. Ec.
RUTH S. HAGGERTY, M.S., ASST. in H. Ec.

HORTICULTURE
F. M. HARRINGTON, M.S., Head
V. E. IVERSON, M.S., Asst. Hort.

IRRIGATION AND DRAINAGE
O. W. MONSON, M.S., Head

VETERINARY RESEARCH
HADLEIGH MARSH, B.S., D.V.M., Head
HOWARD WELCH, B.S., D.V.M., Veterinarian.
E. A. TUNNICLIFF, D.V.M., M.S., Associate Veterinarian.
ANNE NECHANICKY, B.S., Assistant in Veterinary Research.

LIBRARY AND PUBLICATIONS
F. B. LINFIELD, B.S.A., Director Emeritus and Head.
MARGARET DEWEY, B.S., Bulletin Ed.

MISCELLANEOUS
LOUIS G. TRUE, B.S., Ag. Publicity.
LOUISE EAGER, B.S., Sec'y. to Director.
BERNARD COPPING, B.S., Assistant to Secretary and Treasurer.

BRANCH STATIONS

Horticulture Branch Station ..... **Corvallis**
W. E. Pollinger, Superintendent

Huntley Branch Station[12] ..... **Huntley**
Dan Hansen, Superintendent
A. E. Seamans, B.S., Dry Farming — D. V. Kopland, B.S., Dairying

Judith Basin Branch Station[12] ..... **Moccasin**
R. M. Williams, B.S., Superintendent

North Montana Branch Station[12] ..... **Havre**
M. A. Bell, M.S., Superintendent

U. S. Range Livestock Experiment Station[12] ..... **Miles City**
J. R. Quesenberry, M.S., Superintendent
A. L. Baker, B.S., Cattle — E. B. Osborn, B.S., DVM., Horses
R. E. Hutton, B.S., Swine

[11]Organization as of November 30, 1937.
[12]Cooperating with the United States Department of Agriculture.

FINANCIAL SUMMARY

EXPENDITURES OF THE MONTANA AGRICULTURAL EXPERIMENT STATION FOR THE YEAR ENDING JUNE 30, 1937

	Hatch	Adams	Purnell	Bankhead Jones	State and Others*
Salaries	$ 7,043.29	$10,679.63	$32,898.32	$4,917.02	$ 58,197.12
Labor	1,961.80	2,145.20	16,785.81	2,233.00	17,651.29
Stationery and Office	355.72	——	381.97	——	1,703.85
Scientific, consumable	28.49	324.26	1,109.00	8.00	1,258.78
Feeding stuffs	1,101.14	——	402.91	251.95	21,454.74
Fertilizers	——	——	54.55	40.33	204.57
Sundry	375.69	201.37	921.37	43.61	6,534.39
Communication service	410.52	1.57	209.79	26.07	1,077.14
Travel expenses	307.76	690.05	2,147.43	116.39	2,943.33
Transportation of things	34.23	10.41	143.01	——	990.32
Publications	2,260.34	——	2,760.52	——	4,301.90
Heat, light, water, power	2.21	——	193.52	——	4,017.78
Contingent expenses	11.49	——	——	4.43	157.00
Furniture, furnishings, fixtures	103.45	53.38	628.02	——	154.82
Library	459.82	32.16	41.19	——	77.80
Scientific equipment	153.55	858.25	312.23	58.98	122.04
Tools, machinery, appliances	315.50	3.72	730.36	51.80	4,884.37
Livestock	75.00	——	——	——	425.00
Buildings and land	——	——	280.00	——	1,191.97
Totals	$15,000.00	$15,000.00	$60,000.00	$7,751.58	$127,348.21

*This fund includes the following:

State appropriations for Home Station	$50,979.52
For Grain Laboratory and Branch Stations	28,311.31
Income from sales	48,057.38

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